DATA PROCESSING PROCEDURES IN NUMERICAL MESOANALYSIS

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ABSTRACT

Pressure traces taken from microbarograms of first-order and research network stations are prepared for objective analysis on an electronic computer by placing paired numbers of time and pressure on punched cards. Data are evaluated at significant points along the trace in such a way that the trace between recorded points is approximately a straight line. Allowance is made for corrections for slow or fast clock, and deviations between aneroid and mercurial barometric readings are made by the computer. From use of a suitable reference atmosphere, sea level pressures (P^* values) are determined for first-order stations from mean station pressures for some 3-hour period for which all recorded pressure traces are relatively undisturbed. P^* values for network stations are derived from a map analyzed for first-order stations. The mesoanalysis program then produces a sea level (P^*) map for any particular minute in the period of analysis.

Several maps produced by the program are compared with mesomaps produced by manual methods, and with the National Weather Analysis Center analysis. A series of maps at 10-minute intervals is shown which indicates the development and history of individual cells of the mesosystems.

1. INTRODUCTION

The techniques of analysis required to produce a set of charts showing the formation, life history, and decay of mesosystems are both laborious and time-consuming. This serious shortcoming has reduced detailed application of mesoanalysis procedures to a role of post-mortem research. Such research may greatly enhance the forecaster's understanding of weather phenomena on this scale, but offers him little direct aid in visualizing the specific features of mesosystems associated with the current weather situation.

The application of the high-speed electronic computing machines to analyze large-scale weather systems [1] suggests that mesoanalysis techniques can be treated similarly. Although problems in data collection and communications must be solved before the forecaster could be provided with current mesomaps and forecasts, data presently available provide the means of developing the analysis program.

The methods of mesoanalysis which are being adapted to machine methods are essentially those established by Fujita, Newstein, and Tepper [2], and are best applied to continuous recordings of the parameters involved.

In developing this program, a case previously analyzed by hand by Smith, Kaplan, Herman, and Whitney [3] was used as a standard for comparison of results. This situation, on May 7–8, 1956, contained a relatively simple, sharply defined mesosystem. Microbarograph traces for this case are available for approximately 40 first-order stations and from about 175 research network stations in the Oklahoma-Texas area. These instruments are equipped with 12-hour gears, rather than 5-day gears. The charts are changed daily, with two 12-hour traverses normally recorded on each chart.

The data are analyzed for a grid system of 40 columns and 39 rows occupying the large rectangle shown in figure 1. Spacing is such that one grid interval is 22.0 nautical miles, or 25.3 statute miles.

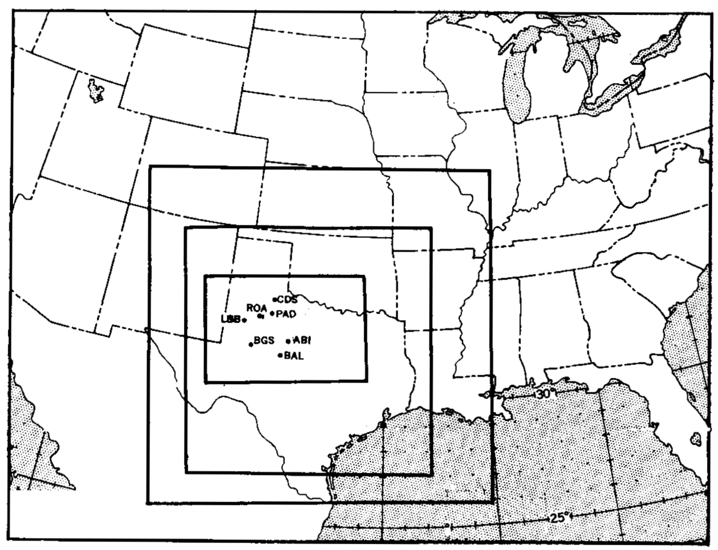

FIGURE 1.—Location of the grid system used by the mesoanalysis program. The largest rectangle defines the boundaries of the grid. The medium-sized rectangle shows the area depicted in figures 8 and 9. The smallest rectangle shows the area depicted in figures 10–22. Observation stations frequently mentioned in the text are Childress (CDS), Paducah (PAD), Roaring Springs (ROA), Lubbock (LBB), Big Spring (BGS), Abilene (ABI), and Ballinger (BAL), all in Texas.

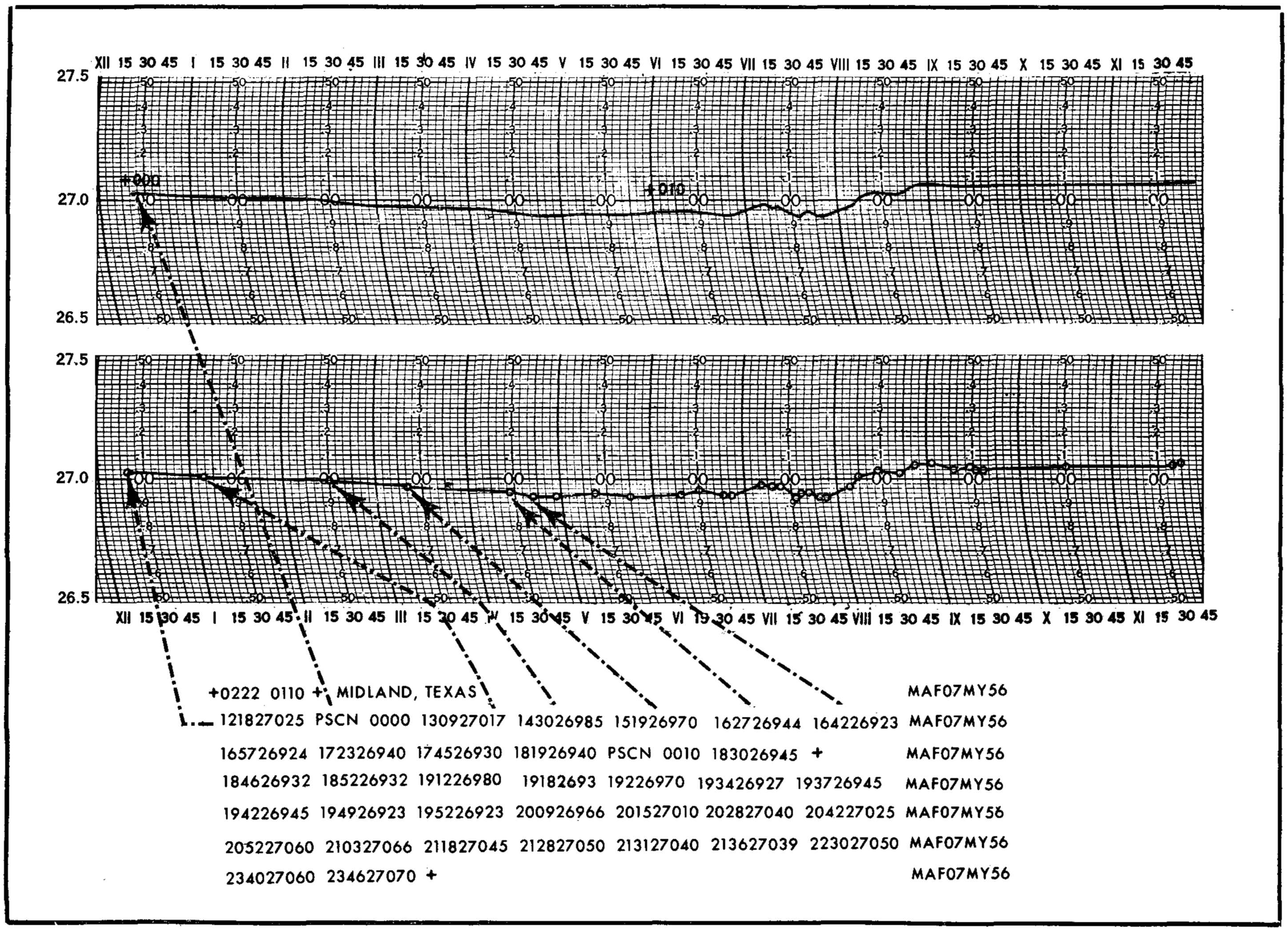

FIGURE 2.—Evaluation of 12-hour microbarograms. At the top is a reproduction of the original trace for Midland, Tex., May 7, 1956, with pressure correction entries made by the observer at synoptic times. In the middle is the same trace drawn as a series of straight lines connecting points selected for evaluation (small circles). At the bottom is the representation of the same trace on punch cards as a tabulation of points selected for evaluation. In each group of nine digits, the first four are the local time and the last five are station pressure in inches of mercury, recorded to thousandths of an inch.

2. EVALUATION OF MICROBAROGRAMS

The initial problem to be solved was that of getting data from microbarograms into the computer. The method chosen was to evaluate the traces much as radiosonde data are evaluated; i.e., to select significant points in such a manner that the trace between the two points can be represented by a straight line. Data are then simply recorded as a series of paired numbers, each pair consisting of a time and a station pressure.

The method of evaluating traces is illustrated in figure 2. The upper portion of this figure is a reproduction of the 12-hour microbarogram for Midland, Tex., a first-order station, for the period from noon to midnight on May 7, 1956. The numbers +000 and +010 indicate the pressure corrections to the trace determined at synoptic times from a comparison with the mercurial barometer.

The middle portion of the figure shows the same trace as points selected to evaluate it connected by straight lines, and demonstrates clearly the irregular dispersion of the necessary points.

The lower portion of the figure shows the format of the data from these points as they are placed on punched cards. The top line shows the station identification by grid row and column coordinates, which is read by the machine, and the station name, which is not processed but identifies the data visually.

The following lines consist of the data pairs for each point. At 1218 CST, the time at which the trace began, the station pressure was 27.025 inches of Hg. The pressure correction of zero, made at this time, immediately follows the point. Then at 1309 CST, the pressure was 27.017 in., at 1430 CST it was 26.985 in., etc. At 1819

FIGURE 3.—Semi-automatic evaluation of microbarograms by a Benson-Lehner Oscar K trace reader (left). The operator adjusts a time line overlay on the microbarogram form by turning a dial. By turning a second dial a pressure calibration overlay is shifted until the two lines intersect on the trace at the time to be read. Pushing a button then causes the digitized values of time and pressure to be punched on a card by the IBM 026 card punch (right). Time intervals are set automatically by the Oscar K at prescribed intervals and the operator must read the time value on the trace to position the time line overlay. Manual over-riding of this automatic stepping procedure is possible. Digitizing of the pressure is done automatically.

CST is was 26.940 in., and the pressure correction for that point was +0.01 inch of Hg.

Unfortunately, a considerable amount of programming was necessary to minimize instrumental and observer error. The abbreviation TMCN (for time correction) is recognized by the program to allow for fast or slow clock in the microbarograph, errors in positioning the form by the observer, and changing of time zones. By giving a time correction of 60 at the beginning and end of a trace, for example, a trace from a station in the Mountain Standard Time zone may be read in local time and changed by the computer to Central Standard Time.

Also, the abbreviation PSCN (for pressure correction) is recognized by the program to allow for deviations between mercurial and aneroid barometric pressure, for possible skewing of the form by the observer when he placed it on the drum, and for certain instances when a microbarograph with a sticky dashpot results in a series of sudden stair-step rises or falls in the trace.

For example, in the use of the pressure correction, consider a chart skewed on the microbarograph by the observer in such a way that the trace leaves one end of the chart at 1159 CST at 29.055 inches of Hg and the same trace begins at the other end of the chart, at 1200 CST, at 29.079 inches of Hg. The chart was placed on the instrument at 1030 CST, at 29.040 inches of Hg.

The evaluator would record the trace as follows, assuming the necessity of adding a significant point at 1130 CST:

103029040 PSCN 0000 113029053 115929055 PSCN 0003 120029079 PSCN–0021

The trace is considered as pivoted about the point at which the chart was placed on the instrument, ⅛ of the distance (1030 CST) from the right end (1159 CST), so that ⅛ of the 0.024 inch skewing error is to be applied at the end of the trace and ⅞ at the beginning. The program applies these corrections linearly interpolated by recorded time along the trace between the points indicated by successive correction symbols. They are applied to the data by the computer as the cards are read. The information, after correction by the computer, would be stored in the memory as if the readings had actually been

103029040 113029055 115929058 120029058

Of course, the same corrections of $+0.003$ and -0.021 would also be entered after the points at 2359 CST and 0000 CST for the second trace on the chart.

Traces are currently evaluated on a Benson-Lehner Oscar K trace reader (fig. 3) which has been modified slightly to count with hours subdivided into 60 units for minutes, rather than into 100 units. An IBM 026 card punch is attached for direct punching of the trace data on cards. Using this equipment a fairly smooth trace for a 24-hour period can be placed on cards in about 10 minutes, while a trace containing a considerable amount of irregularity may take 20 to 25 minutes because of the additional points required. This time includes 2 to 3 minutes for aligning the reader to the trace before actual reading is done.

As the cards are read by the computer the station pressures are also converted to millibars and time is converted from hours to minutes, keeping track of days. That is, every time a trace goes past midnight, an additional 24 hours is added to the recorded times. Also, as the cards are read, separate lists of first-order and network stations are formed.

3. REDUCTION TO SEA LEVEL

Once the station pressure traces have been loaded and corrected, the pressures must all be reduced to some common plane of reference, viz., sea level. For first-order stations, whose heights are known, reduction is not as great a problem as with the network stations which have not been surveyed and whose changes in station pressure are known but whose true station pressures and heights are not. A type of calibration procedure is necessary. The calibration of network traces requires drawing of a smooth map based on first-order stations only.

For this program a slight departure from the procedure described in [2] was introduced. Instead of using the average pressures for the entire period of analysis, including the mesosystems being studied, to obtain a smooth map, the program scans all the traces together to determine the least disturbed period of arbitrary length of 3 hours. In this way it is hoped that any anomalous values of mean station pressures due to the presence of the mesosystems themselves can be reduced or eliminated.

To detect the presence of a mesosystem the program computes the intensity-amplitude (IA) value of each recorded time interval for each trace. The IA value is defined by Tepper [4] as $(\Delta p)^2/\Delta t$, that is, the pressure tendency, $\Delta p/\Delta t$, multiplied again by the pressure difference Δp. The IA value was selected for this purpose, rather than the tendency alone, because of its dependence not only on the slope of the trace, but also on the magnitude of the pressure change. Thus small sharp pressure rises, which may have very large tendency values, will be subdued in favor of large rises associated with the more intense mesosystems.

The maximum IA value for each minute in the period of analysis is determined for all the traces used in the case. The maximum IA value for the 3-hour period begun by each minute is found, and the minimum of these defines the least disturbed or calmest 3-hour period. The average station pressure for this 3-hour period is then computed for each first-order and network station according to the following formula:

$$\bar{p}=\frac{(p_2+p_1)(t_2-t_1)+(p_3+p_2)(t_3-t_2)+\ldots+(p_n+p_{n-1})(t_n-t_{n-1})}{2(t_n-t_1)} \tag{1}$$

where $\bar{p}$ is the mean 3-hour station pressure; t is a recorded time in the 3-hour period; p is a recorded station pressure in the 3-hour period corresponding to time t; t_1, p_1 are the time and station pressure at the beginning of the 3-hour period; t_n and p_n are the time and station pressure at the end of the 3-hour period (beginning and ending times and pressures are found by linear interpolation if not recorded); t_n-t_1 is, by the above definition, 180 minutes.

The number of terms in the numerator of equation (1) may be as few as one or as many as 179, depending on the number of data points recorded in the 3-hour period for any one station. The normal range is 6 to 18.

In reducing the first-order stations to sea level, a pressure-type quantity is required which must fulfill two conditions: (1) The local change in this quantity must equal the change in station pressure in order to preserve the intensity of the mesosystems and facilitate reducing traces. (2) Given this quantity and the height of a station or terrain at a geographical location, the station pressure at that location can readily be found. This second condition is required by the upper-air studies which will be made in the future.

The quantity which fulfills both of these conditions was conceived by Smith, Kaplan, Herman, and Whitney [3], and was identified by them as P^*. It originally used the ICAO Standard Atmosphere as a reference.

The derivation of this quantity, somewhat expanded beyond the original derivation, is as follows:

The basic requirement for P^*, that of equal change of P^* for equal change in station pressure can be expressed as

$$\frac{\partial P^*}{\partial t}=\frac{\partial P_s}{\partial t} \tag{2}$$

where P_s is the station pressure and t is time. Integration produces

$$P^*=P_s+K \tag{3}$$

where K is a constant of integration.

K can be defined in such a manner that when $P_s=P_{rs}$, the reference atmospheric pressure corresponding to station height, Z, then $P^*=P_{ro}$, the reference atmosphere sea level pressure (1013.25 mb. for the ICAO Standard Atmosphere). Then

$$K=P_{ro}-P_{rs} \tag{4}$$

and

$$P^*=P_s+P_{ro}-P_{rs} \tag{5}$$

Since the ICAO Standard Atmosphere was used by Smith et al. [3], this is as far as the derivation was carried. However, the maps produced by using the ICAO Standard Atmosphere as the reference atmosphere do not agree too well with the sea level pressure maps produced by National Weather Analysis Center. There was generally a tendency toward too high P^* values in plateau and mountain areas. The need for using a warmer, more suitable reference atmosphere was apparent. It would be possible to place a different reference atmosphere table, which would have to be computed in any event, in the computer memory. But it is more efficient to derive the relationship between P_s and P^* for any reference atmosphere and let the computer solve the resulting equation for each first-order station and its particular height above sea level. The derivation of P^* in equation (5) must therefore be extended.

The mean temperature, $\overline{T}$, of the layer from sea level to station height, defined from the reference atmosphere, is

$$\overline{T}=T_{ro}+\frac{LZ}{2}+273.16 \tag{6}$$

where T_{ro} is the sea level temperature of the reference atmosphere (ICAO, 15° C.), and L is the reference atmosphere lapse rate (ICAO, $-1.9812°$ C./1000 ft.).

From the hydrostatic equation

$$P_{rs}=P_{ro}e^{-gZ/(R\overline{T})} \tag{7}$$

where g is the acceleration of gravity and R is the gas constant for dry air. Substituting in (5),

$$P^*=P_s+P_{ro}(1-e^{-gZ/(R\overline{T})}) \tag{8}$$

The factor $(1-e^{-gZ/(R\overline{T})})$ can be expressed as a rapidly convergent series with alternating signs that may be considered terminated when one individual term becomes smaller than the accuracy required. Replacing this factor in (8) with its series expansion produces

$$P^*=P_s+P_{ro}\left[\frac{gZ}{R\overline{T}}-\frac{1}{2!}\left(\frac{gZ}{R\overline{T}}\right)^2+\frac{1}{3!}\left(\frac{gZ}{R\overline{T}}\right)^3-\frac{1}{4!}\left(\frac{gZ}{R\overline{T}}\right)^4+\ldots\right] \tag{9}$$

This is the equation solved by the program for the first-order stations in the area, using as P_s the average station pressure for the 3-hour period, $\overline{p}$, as determined in equation (1).

The smoothed 3-hour map for these stations is then analyzed for the rectangular grid array and for the locations of the network stations.

The difference between the average 3-hour P^* value for each network station location and the mean station pressure ($\overline{p}$) for the 3-hour period for that station is used for calibration. Because the P^* quantity changes by the same amount as station pressure, this difference for each station is simply added to all the station pressures recorded in the trace to produce a P^* trace for that station. First-order stations are treated in the same way except that the 3-hour P^* values are those obtained directly from the sea level reduction. The resulting P^* traces are stored on a magnetic tape.

The program then reads a print control card which specifies the day, hour, and minute of the map to be printed. The P^* traces are read from the tape on which they are stored and the pressure for each station at this particular minute is found by linear interpolation from data points defining the trace. A map for this minute is then analyzed in the same manner as the smooth, 3-hour map, but now using both first-order and network stations.

Figure 4 reviews the order of the cards required by the program. The first, in the lower left corner, defines the period of analysis. The second restricts the analysis to the region of particular interest in the main grid array, to minimize machine time required for each case. The third defines the reference atmosphere. In this case an atmosphere 12° C. warmer than the ICAO Standard Atmosphere was used, but with the same lapse rate. This is a seasonal variation which fits this area better at this time than the ICAO Standard Atmosphere. Then follow the station pressure traces, which for this case numbered about 2,000 cards, and, finally, the print controls.

4. ERROR DETECTION

The data cards are first test-loaded on the computer in small batches of four to eight stations prior to the production run, to eliminate coarse errors such as punching errors, times out of order, and gross errors in pressure evaluation. The entire set of data is then processed to detect certain errors of observation and evaluation.

The first time this case was run on the computer the pressure systems, which were well defined at the beginning

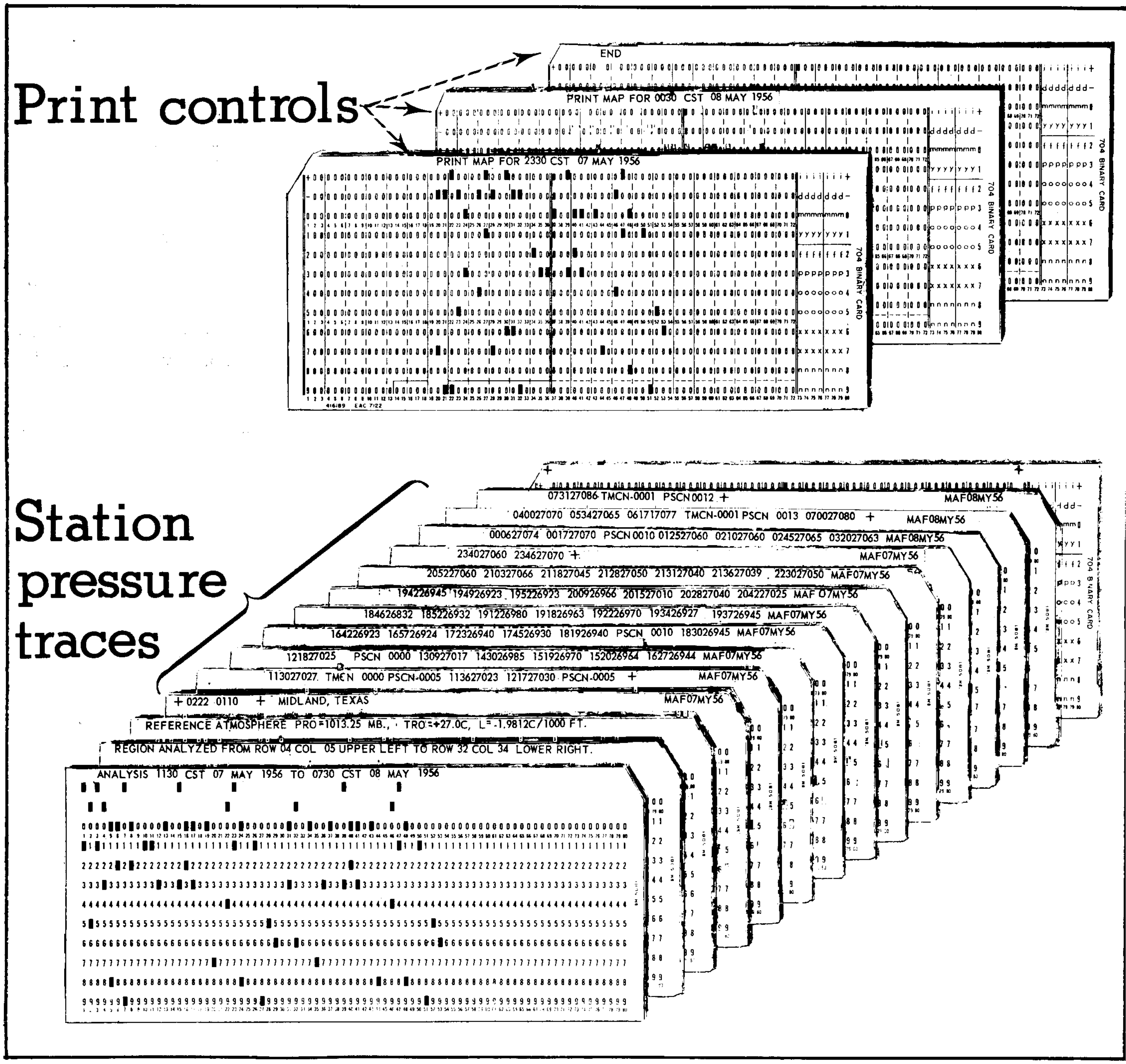

Figure 4.—Control cards and data cards for the mesoanalysis program. The first three cards define the period of analysis, the region of the grid to be analyzed, and the reference atmosphere in terms of sea level pressure and temperature and lapse rate. Then follow the station pressure traces, and finally the print controls specifying each particular minute for which the data are to be analyzed.

of the period at the time of the smooth map, showed a gradual degradation as time went on, until at the end of the period of analysis, 0730 cst of May 8, 1956, farthest from the least disturbed 3-hour period, a large number of small disorganized cells greatly obscured the main features of the map. At first it seemed that the trouble was due to the fact that the calibrations at network stations from the smooth map were not sufficiently precise to last through the entire period. However, a careful examination of the traces involved revealed a number of errors of observation or evaluation.

The most common one was caused by intersection of traces as they were being recorded. Since the drum on the accelerated microbarograph rotates twice in a 24-hour period, the traces produced often intersect or overlap. This situation demands judgment on the part of the

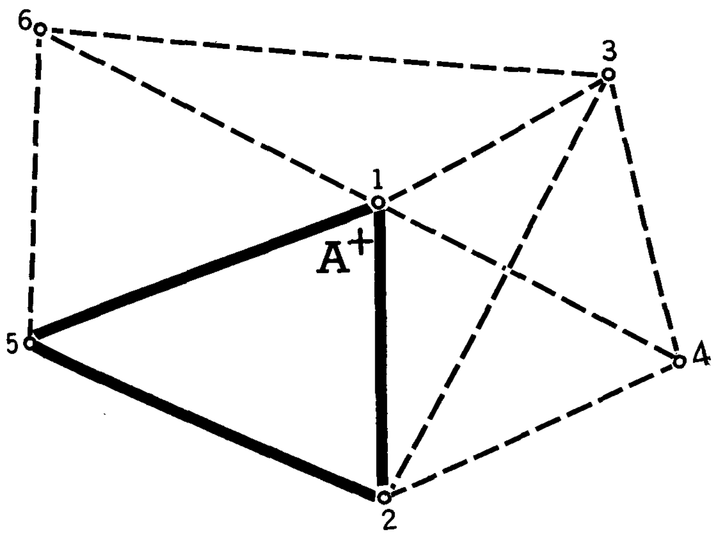

Figure 5.—Objective analysis scheme for mesoanalysis program' The cross marked A represents the point for which a P^* value is to be obtained. Numbered circles represent points where observations are made. Numbers are in order of increasing distance of observation point from A. Dashed lines represent possible triangles which the program may consider in selecting one for analysis. Heavy lines represent triangle selected, which encloses analysis point A.

evaluator to select the correct trace for each 12-hour period. In certain cases the wrong decision was made with the result that data were occasionally 12 hours off.

For one station, Ballinger, Tex., the observer did not label the trace with the correct date. The persistent anomalous pressure of Ballinger outside of the smooth 3-hour period indicated the trouble, whereas the use of the entire analysis period for the smoothed map in the hand analysis tended to obscure the error.

After correction of the traces for errors of this type, the data are ready for final processing. The production run for the case shown here with these errors removed vindicated the use of the 3-hour smoothed map in the calibration process. No observable drift in calibration for any station from the beginning to the end of the analysis period can be detected.

5. OBJECTIVE ANALYSIS

Without going into great detail on the objective analysis procedure, the general scheme used for the maps in this paper is shown in figure 5. The point for which the P^* value is to be analyzed is designated by the letter A. Points where observations were made are at the small numbered circles, and the number designates the nearness of the observation point to point A. The program performs a proximity search on all the stations until it finds the nearest three which form an enclosing triangle for point A, shown in heavy black lines as triangle 1–2–5. Triangles 1–2–3, 1–2–4, and 1–3–4 do not enclose the point A, even though their stations are closer to it, a are therefore rejected. The P^* value at A is determin by fitting a plane to the P^* values at stations 1, 2, and and computing the value for the plane at A.

Isobars obtained by this scheme are straight-line se ments through the triangle, but when the grid points a evaluated by the contouring program, curvature appea The detail presented is limited principally by the size the triangles, which are approximately grid size in t network area.

A method directly producing curvature of isob through the triangle has been developed, and will described in detail later. Nevertheless, in its prese state the program is capable of producing maps whi compare quite well both with the NAWAC analysis f large-scale features and with the maps produced by Smi et al. [3] in their hand mesoanalysis of the case of M 7–8, 1956.

6. COMPARISON WITH MAPS PRODUCED FROM OTHER SOURCES

The period of analysis for this case was from 1130 c May 7, to 0730 cst May 8, 1956. The program select 1130 to 1430 cst as the least disturbed 3-hour period.

Figure 6 shows the NAWAC analysis for 1230 c May 7, 1956. The main features to note are the rid over the north-central United States, the weak rid extending south through Arkansas and Louisiana, t general low pressure in Mexico and the Big Bend ar of Texas, and the front extending from eastern Oklahor through northern Texas.

Figure 7 shows the 3-hour average P^* map for the lea disturbed period, 1130 to 1430 cst. Isobars are for 1-m intervals. Note the high pressure to the north, in Kans and Missouri, the chain of weak high pressure cells in t southeast through Arkansas and Louisiana into the G of Mexico, and low pressure in the southwest, all corr sponding to the features pointed out for the 1230 c NAWAC map (fig. 6). The hatched band across the m locates minimum pressures obtained from adjacent gr points vertically or diagonally, approximately normal the direction of the isobars, to define a trough. The po tion of this trough agrees quite well with the analyz position of the front (fig. 6).

Figures 8 and 9 illustrate the present capability of t program in producing the same results as those obtain by hand analysis. Figure 8 shows the mesosystem at i maximum intensity of development at 2330 cst May 1956, located over the area including Abilene (AB Big Spring (BGS), and Childress (CDS), Tex. The ha analysis on the left (fig. 8a) shows the High consisti of two cells with the western one more extensive. A we trough separates the two cells on the north portion the system. A small meso-Low lies to the west-nort west, over Lubbock (LBB). To the southeast is a seco small Low over Ballinger. A weak butterfly-shaped rid extends eastward from the Highs.

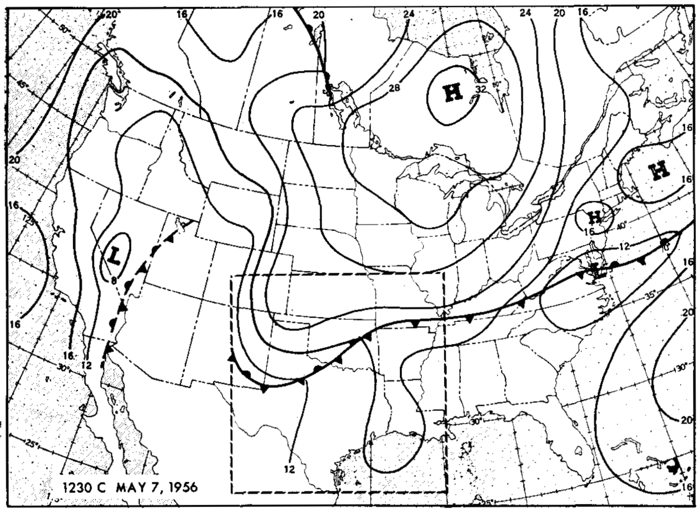

Figure 6.—NAWAC analysis for 1230 cst May 7, 1956, near the beginning of the period of analysis. The geographical area analyzed for the least disturbed period by the mesoanalysis program in figure 7 (south-central United States) is outlined by dashed lines. Isobars are at 4-mb. intervals.

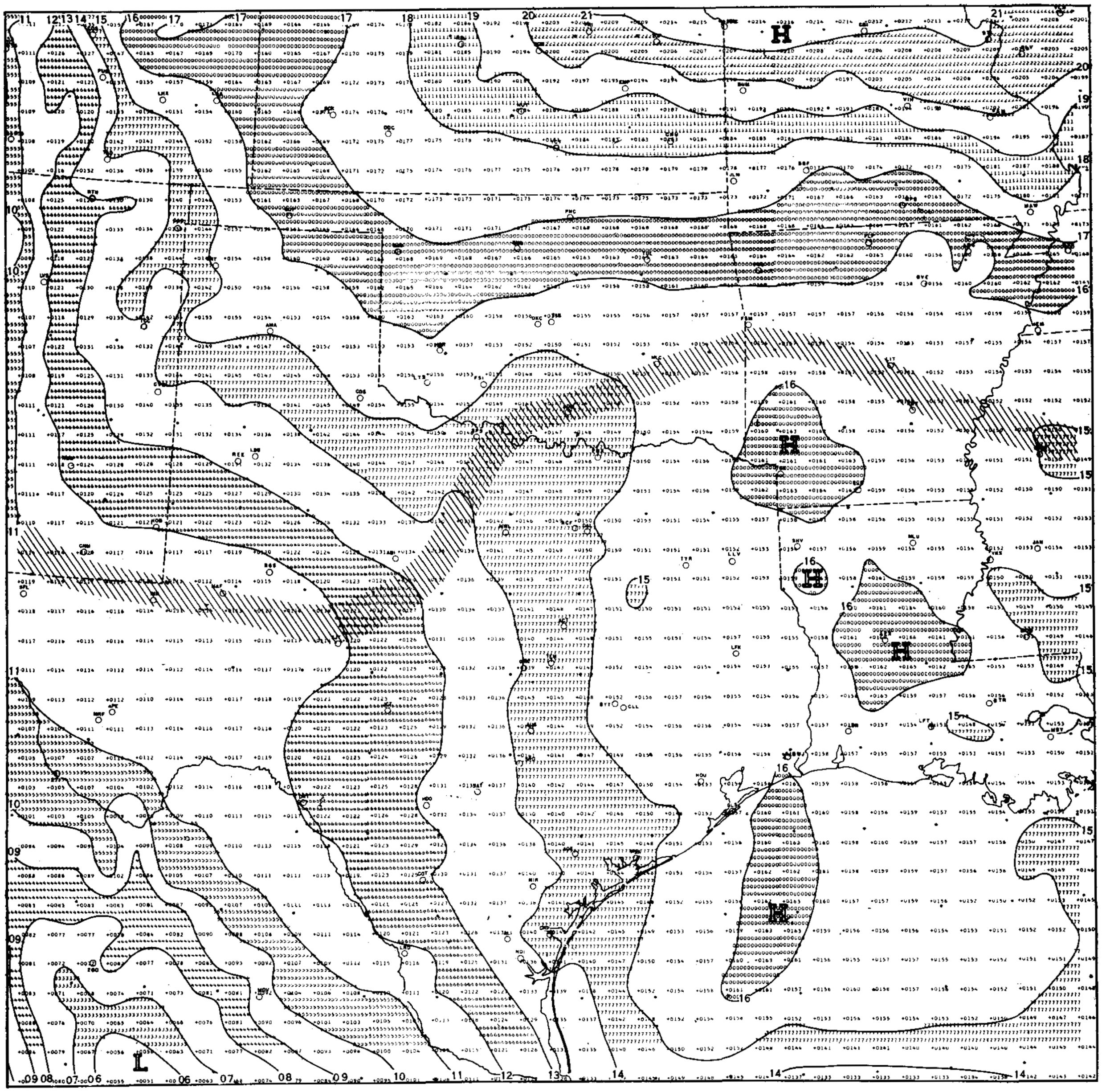

Figure 7.—Average P^* map for least disturbed period selected by the program as 1130 to 1430 cst, May 7, 1956. Isobars are at 1-mb. intervals. Thousands and hundreds values on labels are omitted, so that 12 is actually 1012 mb. The hatched band shows the location of a pressure minimum along vertical or diagonal rows of grid points.

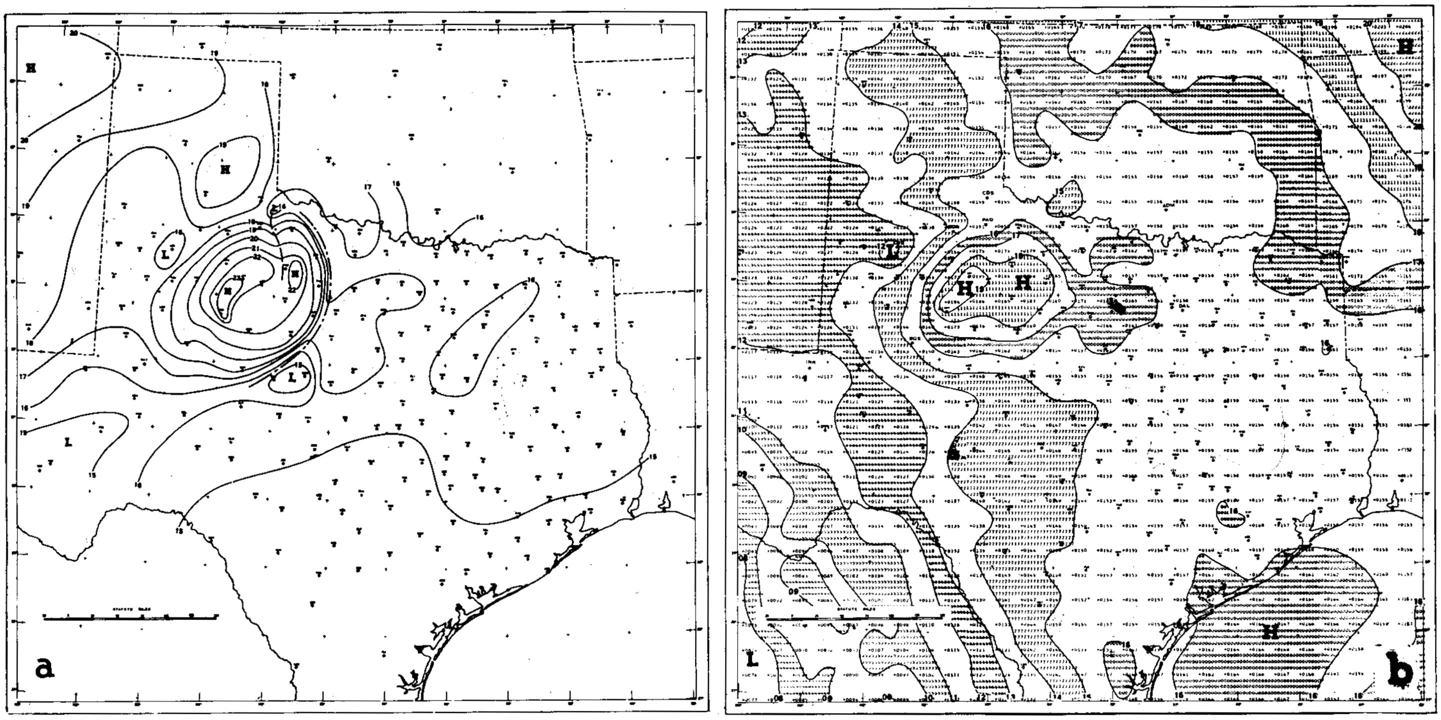

Figure 8.—A comparison of (a) hand mesoanalysis (from [3]), and (b) machine meso-scale analysis for 2330 cst, May 7, 1956. Isobars are at 1-mb. intervals and labeled as in figure 7.

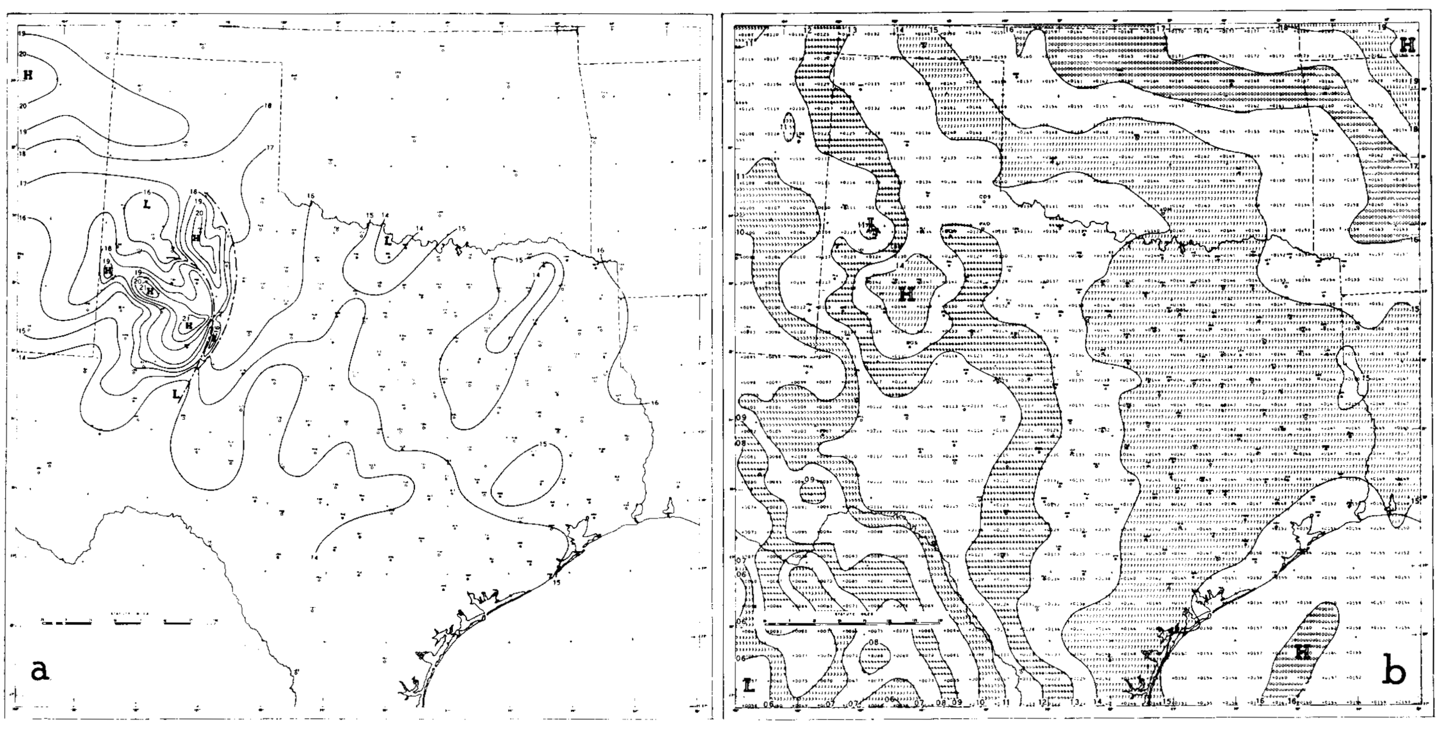

Figure 9.—A comparison of (a) hand mesoanalysis (from [3]), and (b) machine meso-scale analysis for 2030 cst, May 7, 1956. Isobars are at 1-mb. intervals and labeled as in figure 7.

The same general features are apparent in the machine analysis in figure 8b, with the exception of the Low to the southeast over Ballinger. This was due in the hand analysis to the mis-dating of the traces at Ballinger, as previously explained, and was corrected for the machine analysis.

The main difference in pressure values between the hand analysis and machine analysis is due to the difference in the reference atmosphere used in P^* reduction. In the hand analysis the reference atmosphere was the ICAO Standard Atmosphere, while for the machine analysis a reference atmosphere 12° C. warmer was used. The important thing to be considered here in the comparison of the maps is the location and shape of the meso-Highs and Lows, and the approximate gradients.

The machine-produced maps are not, at this point in the development of the program, mesoanalyses in the strictest sense, since they are based on linear interpolation between point values for a fairly dense network of stations. There has been no attempt yet to equate time and space gradients to fill in the detail between network stations, as was done in the hand analysis, and which is the basis of the originally developed technique of mesoanalysis [2].

Analyses which are not based on this principle should properly be called meso-scale analyses rather than mesoanalyses.

This difference is illustrated in figure 9 where the hand analysis and the machine analysis for 2030 CST May 7, 1956 are compared. The machine analysis in figure 9b shows a single high cell located in the area of Lubbock and Big Spring, Tex., with a weak ridge extending northwestward from it, and a small meso-Low on the northwest side of the High, just north of the ridge. The hand analysis in figure 9a shows that the High is actually a ridge of three distinct cells which corresponds roughly to the weak ridge detected on the machine analysis. The Low on the northwest side of the High is actually more extensive than the machine analysis shows, with a trough extending into the center of the area of high pressure in the machine analysis, and separating a fourth high pressure cell on the northeast side. It is evident that the machine analysis based on point values only, produces a considerable amount of undesirable smoothing.

7. MAP SEQUENCE SHOWING CELLULAR DEVELOPMENTS

Once the traces have been recorded on magnetic tape, the mesoanalysis program can obtain maps at more frequent intervals than could be done practically by hand for only a small amount of additional machine time and little additional manual effort. One feature of mesosystems which has not been easy to detect on hourly mesoanalyzed maps is the propagation of the mesosystems by development of additional cells, usually to the northeast or east of the older cell. Several examples of this are evident in this situation. One of the best examples in this case is shown in figures 10–22, a series showing the area around the main mesosystems at 10-minute intervals from 0010 CST through 0210 CST May 8, 1956.

Figure 10 at 0010 CST shows the mesosystem essentially as a single high cell (H_1). By 0020 CST (fig. 11) a new cell (H_2) can be detected forming on the northeastern edge of the older cell. Growth of the new cell ceased between 0020 and 0030 CST. Then between 0030 CST (fig. 12) and 0040 CST (fig. 13), a third cell (H_3) suddenly appeared. Study of other maps in this 10-minute interval indicates that the cell H_3 was just barely noticeable at 0036 CST and grew in 4 minutes to its maximum areal extent of approximately 2,500 square miles (approximately 2 grid intervals square).

For a time (figs. 14–17) all three cells seemed to exist side by side, but after 0130 CST (fig. 18) the first two cells (H_1 and H_2) began to decay rapidly. By 0150 CST (fig. 20) H_1 was less intense than the third cell H_3. By 0200 CST (fig. 21) a fourth cell (H_4) was developing to the northeast of the third, the first had almost completely vanished, and the second is undetectable on the figure. By 0210 CST (fig. 22) the first cell was virtually gone, and the fourth cell was expanding somewhat.

Of particular interest also is the small low pressure area to the northwest of the first cell in most of these figures. It is not evident except as a trough oriented ENE–WSW at 0010 CST (fig. 10), although it appears to be the same one to the northwest of the meso-Highs at 2030 and 2330

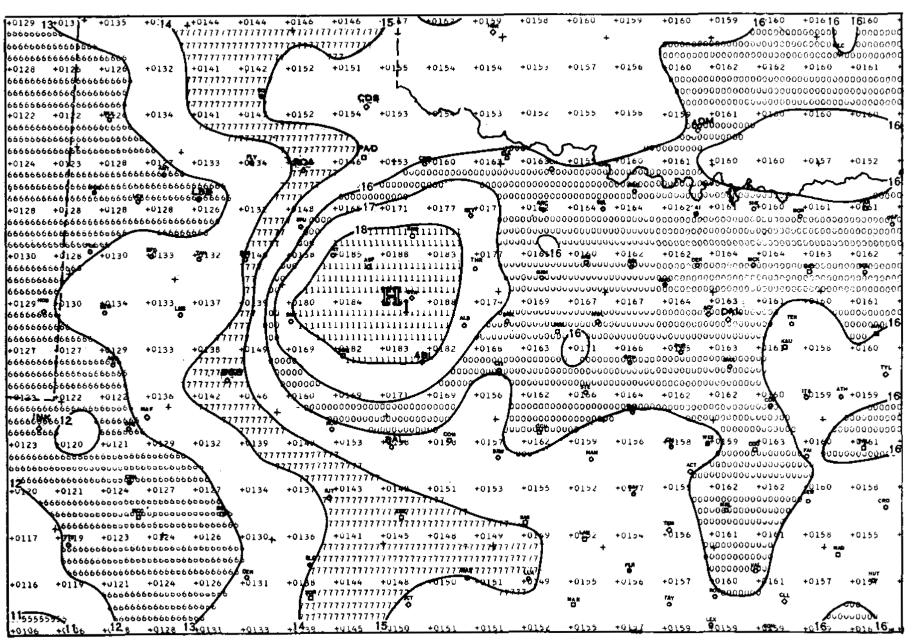

FIGURE 10.—Meso-scale analysis for 0010 CST, May 8, 1956. Isobars are at 1-mb. intervals and labeled as in figure 7.

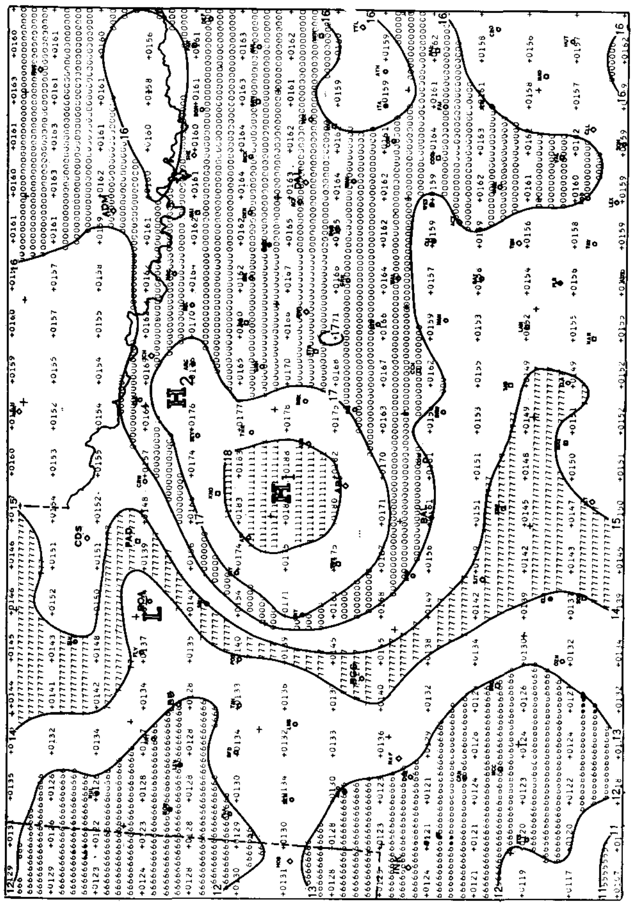

FIGURE 11.—Meso-scale analysis for 0020 CST, May 8, 1956.

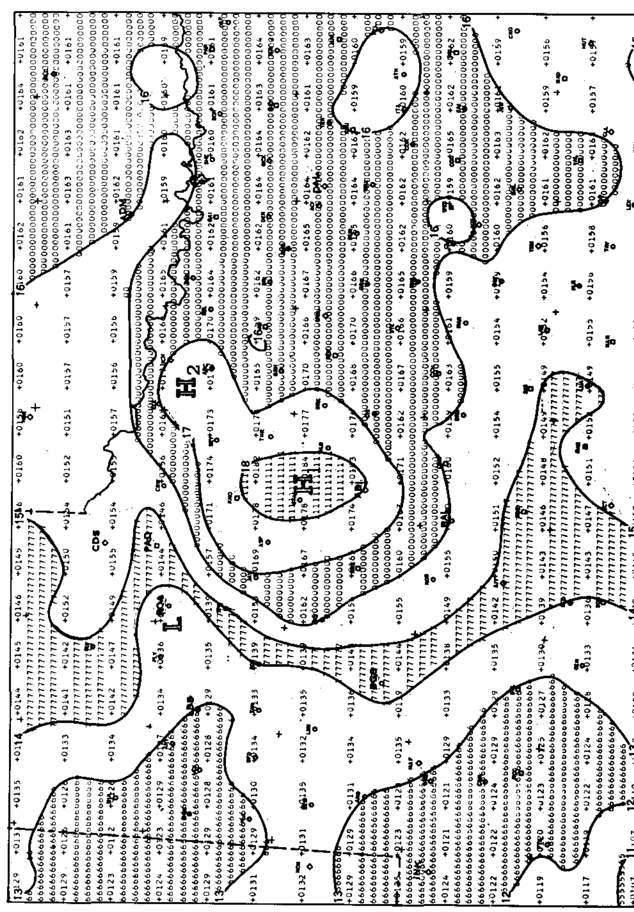

FIGURE 12.—Meso-scale analysis for 0030 CST, May 8, 1956.

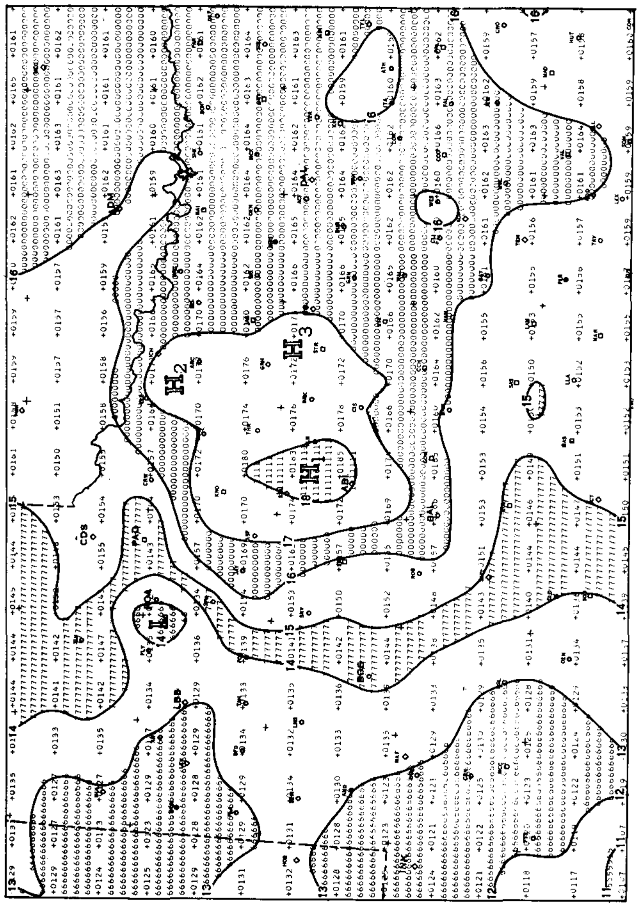

FIGURE 13.—Meso-scale analysis for 0040 CST, May 8, 1956.

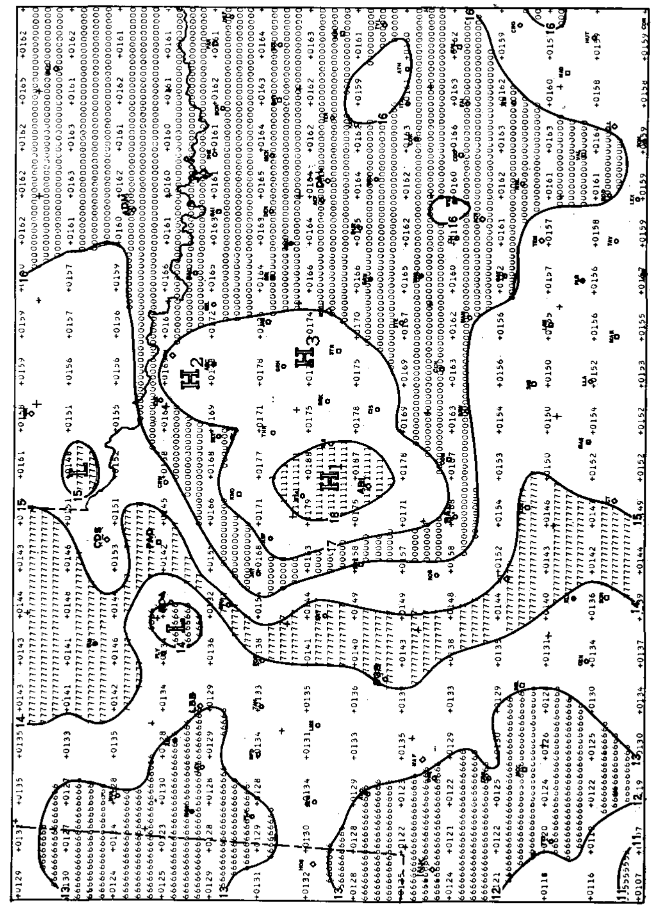

FIGURE 14.—Meso-scale analysis for 0050 CST, May 8, 1956.

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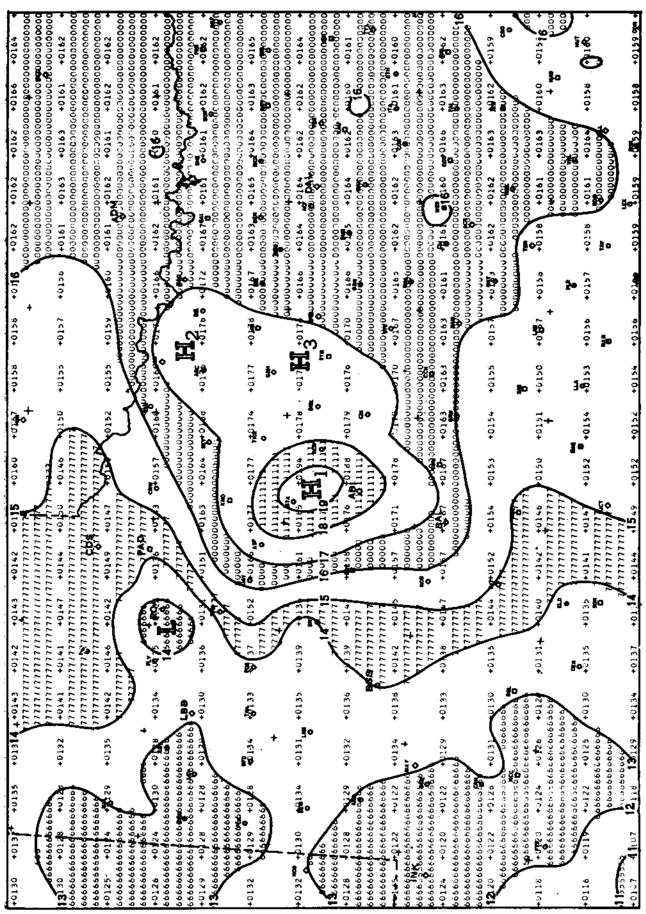

FIGURE 15.—Meso-scale analysis for 0100 CST, May 8, 1956.

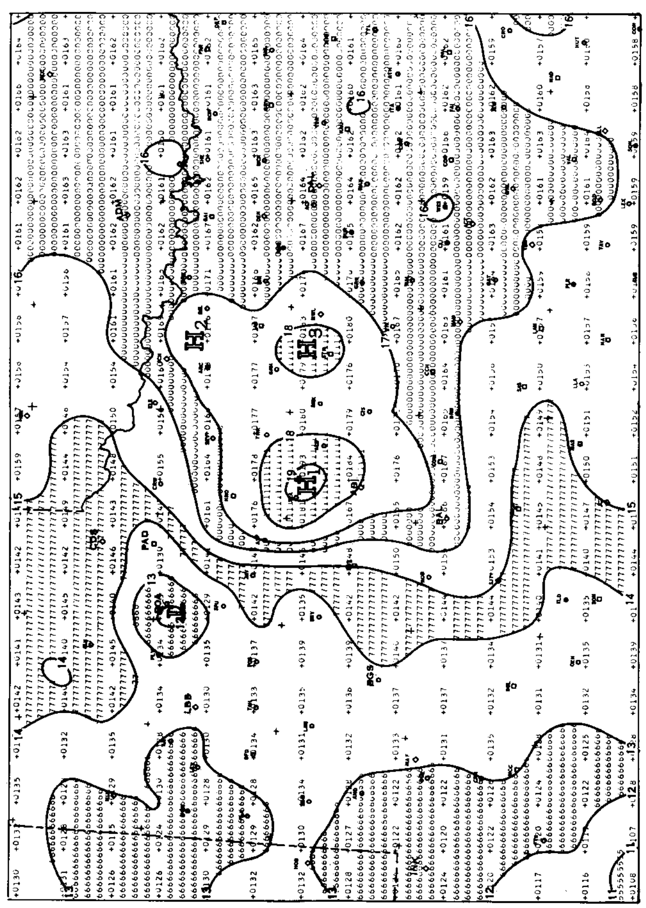

FIGURE 16.—Meso-scale analysis for 0110 CST, May 8, 1956.

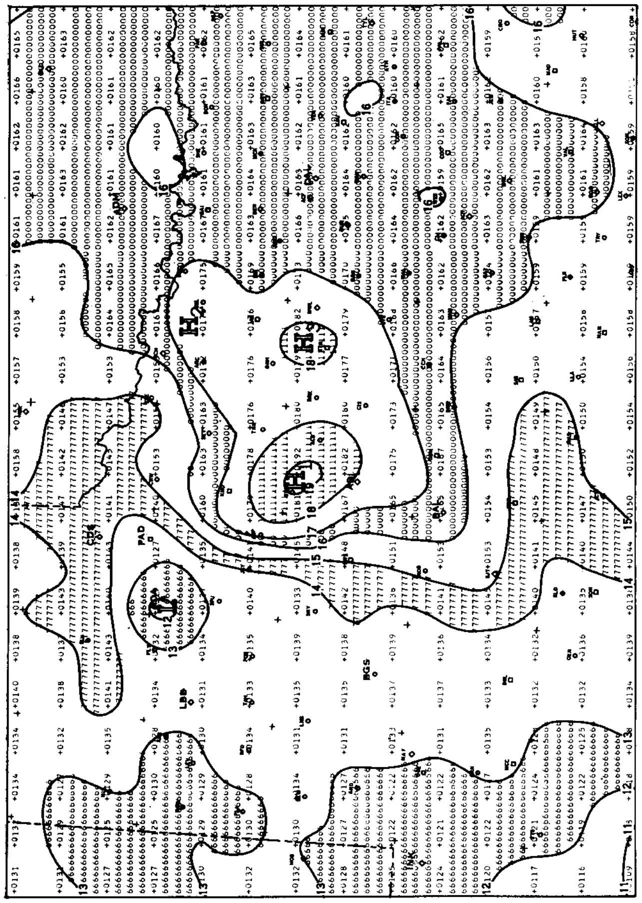

FIGURE 17.—Meso-scale analysis for 0120 CST, May 8, 1956.

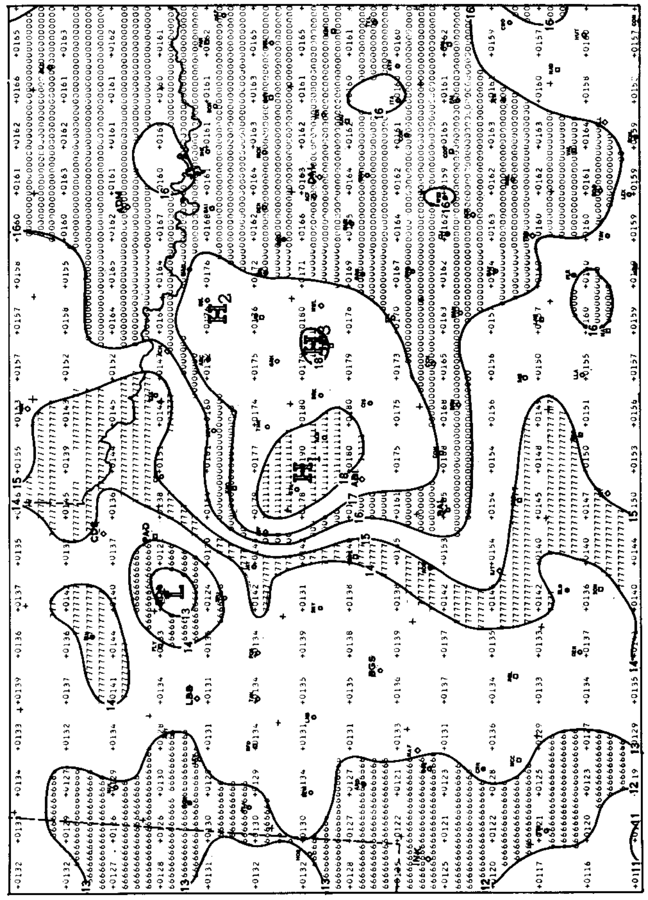

FIGURE 18.—Meso-scale analysis for 0130 CST, May 8, 1956.

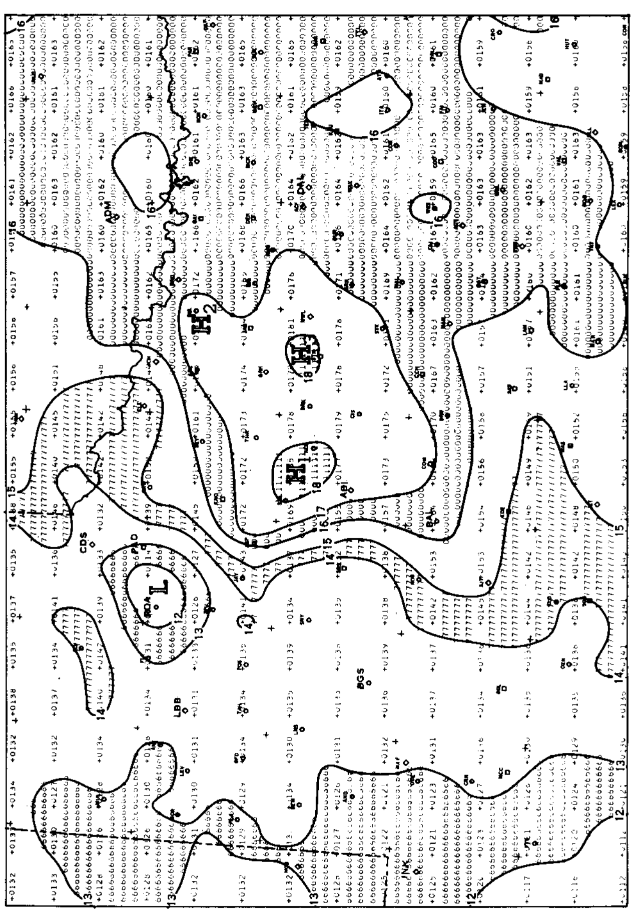

FIGURE 19.—Meso-scale analysis for 0140 CST, May 8, 1956.

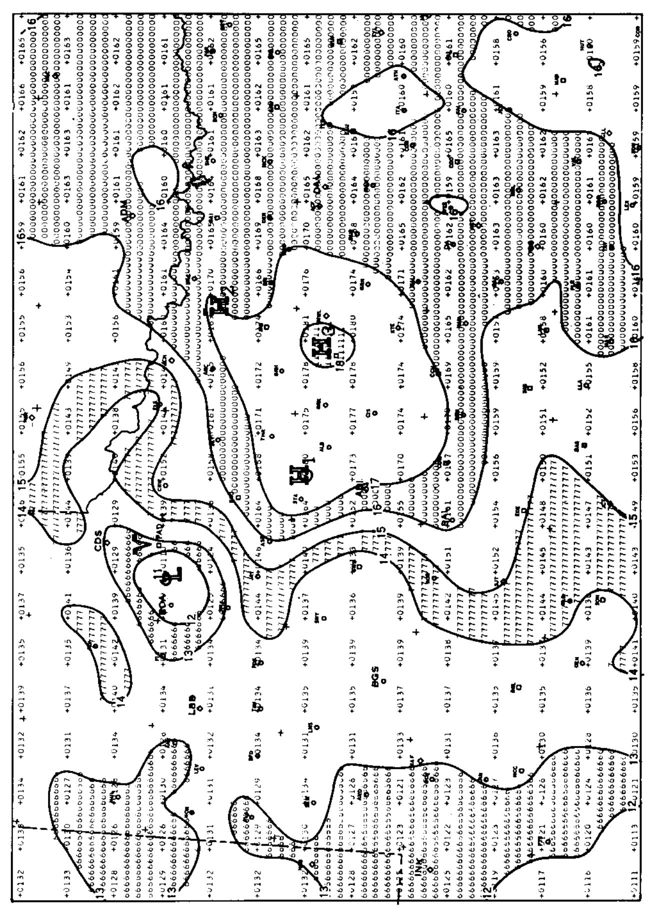

FIGURE 20.—Meso-scale analysis for 0150 CST, May 8, 1956.

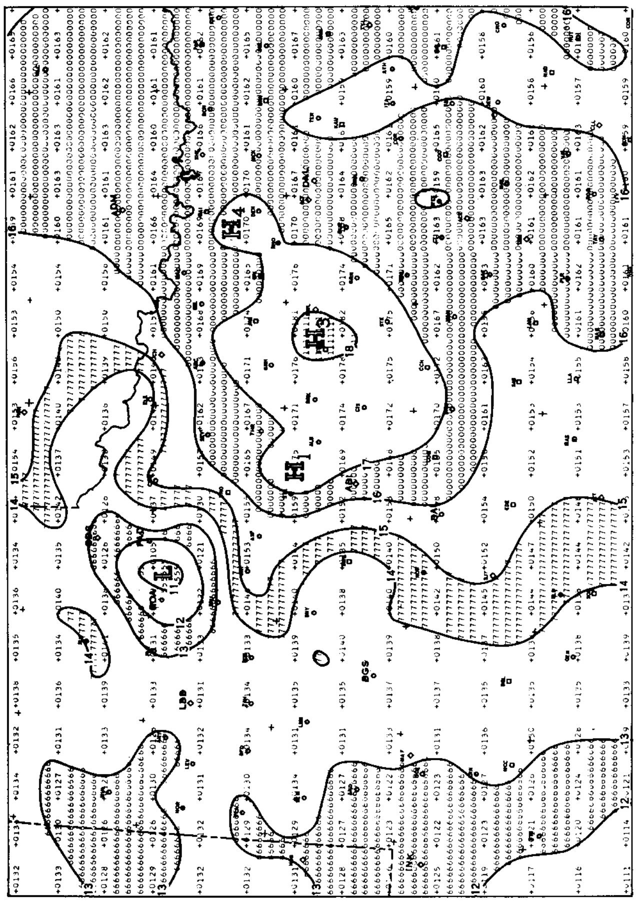

FIGURE 21.—Meso-scale analysis for 0200 CST, May 8, 1956.

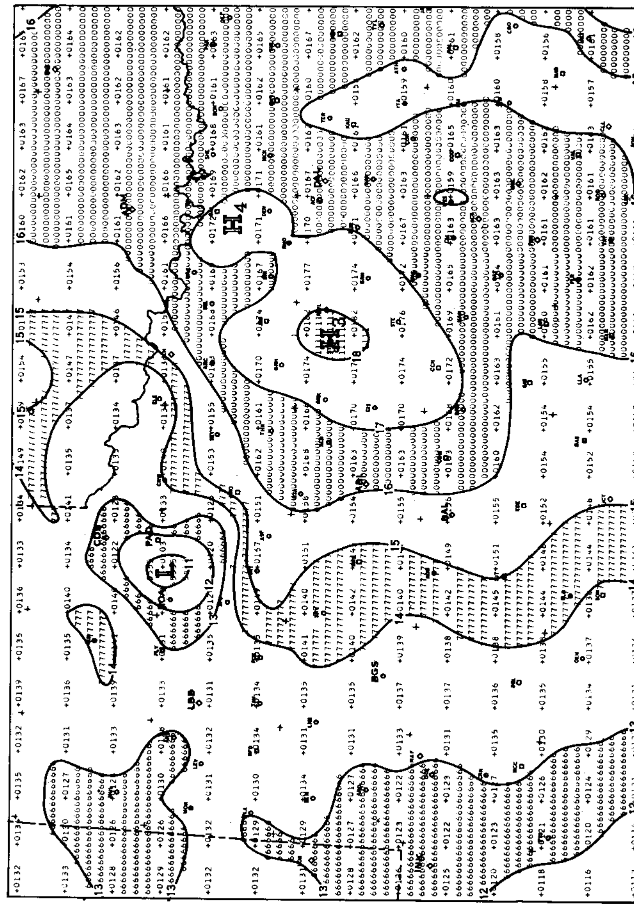

FIGURE 22.—Meso-scale analysis for 0210 CST, May 8, 1956.

CST (figs. 9 and 8). By 0020 CST (fig. 11) it had again become a definite low center with a central pressure at 1013.4 mb. near Roaring Springs, Tex. By 0040 CST (fig. 13) it had deepened considerably to 1012.4 mb. For the next hour the Low moved east-northeastward without much change in intensity. By 0140 CST (fig. 19), having deepened still further, it was located just to the west of Paducah, Tex., where at 0145 CST a tornado was reported. Movement of the tornado was from southeast to northwest. Although its exact location with respect to the network station at Paducah is unknown, the tornado definitely was located on the east side of the Low. The network observer reported the winds slacked off at 0210 CST when Paducah recorded its minimum pressure. This particular Low and its associated tornado activity were also noted by Smith et al. [3].

8. CONCLUSIONS

It has been possible to digitize microbarograms semi-automatically and process the data on an electronic computer, correcting certain observational errors, reducing first-order station pressures to sea level, and calibrating unsurveyed research network stations, to produce analyzed maps which agree in considerable detail with mesoanalyses performed by hand. Use of the computer has greatly improved the facility for analyzing data at short intervals on the order of minutes, which makes it possible to show in detail the growth and decay process of individual cells in the mesosystem. While there is some loss of important detail by unwanted smoothing which is due to the use of a uniformly spaced grid, the program is being improved to produce maps more in agreement with those which can be obtained by manual mesoanalysis methods.

The program was originally written for an IBM 704 and is run on the IBM 7090 with a compatability program.

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